8-29-2007

FINAL REPORT An Assessment of Sea Scallop Abundance and Distribution in Selected Closed Areas: Georges Bank Area I, Nantucket Lightship and Elephant Trunk

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Award Number: NA06NMF4540260

Submitted to:

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VIMS Marine Resource Report No. 2007-7

August 29, 2007

Project Summary

As the spatial and temporal dynamics of marine ecosystems have recently become better understood, the concept of entirely closing or limiting activities in certain areas has gained support as a method to conserve and enhance marine resources. In the last decade, the sea scallop resource has benefited from measures that have closed specific areas to fishing effort. As a result of closures on both Georges Bank and in the mid-Atlantic region, biomass of scallops in those areas has expanded. As the time approaches for the fishery to harvest scallops from the closed areas, quality, timely and detailed stock assessment information is required for managers to make informed decisions about the re-opening.

During June through August of 2006, two experimental cruises were conducted aboard commercial sea scallop vessels. At pre-determined sampling stations within the exemption areas of Closed Area I (CAI) and Nantucket Lightship Closed Area (NLCA) and the entire Elephant Trunk Closed Area (ETCA) both a NMFS survey dredge and a standard commercial dredge were simultaneously towed. From these cruises, fine scale survey data was used to assess scallop abundance and distribution in the closed areas. This data will also provide a comparison of the utility of using two different gears as survey tools in the context of industry based surveys. The results of this study will provide additional information in support of upcoming openings of closed areas within the context of rotational area management.

Project Background

The sea scallop, *Placopecten magellanicus,* supports a fishery that in 2005 landed 56.7 million pounds of meats with an ex-vessel value of US $433 million. These landings resulted in the sea scallop fishery being the most lucrative fishery along the East Coast of the United States (Van Voorhees, 2006). While historically subject to extreme cycles of productivity, the fishery has benefited from recent management measures intended to bring stability and sustainability. These measures included: limiting the number of participants, total effort (days-at-sea), gear and crew restrictions and most recently, a strategy to improve yield by protecting scallops through rotational area closures.

Amendment #10 to the Sea Scallop Fishery Management Plan officially introduced the concept of area rotation to the fishery. This strategy seeks to increase the yield and reproductive potential of the sea scallop resource by identifying and protecting discrete areas of high densities of juvenile scallops from fishing mortality. By delaying capture, the rapid growth rate of scallops is exploited to realize substantial gains in yield over short time periods. In addition to the formal attempts found in Amendment #10 to manage discrete areas of scallops for improved yield, specific areas on Georges Bank are also subject to area closures. In 1994, 17,000 km^2 of bottom were closed to any fishing gears capable of capturing groundfish. This closure was an attempt to aid in the rebuilding of severely depleted species in the groundfish complex. Since scallop dredges are capable of capturing groundfish, scallopers were also excluded from these areas. Since 1999, however, limited access to the three closed areas on Georges Bank has been allowed to harvest the dense beds of scallops that have accumulated in the absence of fishing pressure.

In order to effectively regulate the fishery and carry out a robust rotational area management strategy, current and detailed information regarding the abundance and distribution of sea scallops is essential. Currently, abundance and distribution information gathered by surveys comes from a variety of sources. The annual NMFS sea scallop survey provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. In contrast to the NMFS survey that utilizes a dredge as the sampling gear, the resource is also surveyed photographically. Researchers from the School for Marine Science and Technology (SMAST) are able to enumerate sea scallop abundance and distribution from images taken by a camera system mounted on a tripod lowered to the substrate (Stokesbury, 2002). Prior to the utilization of the camera survey and in addition to the annual information supplied by the NMFS annual survey, commercial vessels were contracted to perform surveys. Dredge surveys of the following closed areas have been successfully completed by the cooperative involvement of industry, academic and governmental partners: CAII was surveyed in 1998, Georges Bank Closed

Area I (CAI), NLCA, Hudson Canyon Closed Area (HCCA) and Virginia Beach Closed Area (VBCA) in 1999, HCCA and VBCA in 2000, NLCA, CAII and the ETCA in 2005. This additional information was vital in the determination of appropriate Total Allowable Catches (TAC) in the subsequent re-openings of the closed areas. This type of survey, using commercial fishing vessels, provides an excellent opportunity to gather required information and also involve stakeholders in the management of the resource.

The recent passing of Amendment #10 has set into motion changes to the sea scallop fishery that are designed to ultimately improve yield and create stability. This stability is an expected result of a spatially explicit rotational area management strategy where areas of juvenile scallops are identified and protected from harvest until they reach an optimum size. Implicit to the institution of the new strategy, is the highlighted need for further information to both assess the efficacy of an area management strategy and provide that management program with current and comprehensive information. In addition to rotational management areas, access to the scallop biomass encompassed by the Georges Bank Closed Areas is vital to the continued prosperity of the fishery.

The survey cruises conducted during the spring/summer of 2006 supported effective area management by providing a timely and detailed assessment of the abundance and distribution of sea scallops in the access areas of CAI, NLCA and the entire ETCA. The information gathered on these survey cruises will augment information gathered by the annual NMFS sea scallop survey which provides a comprehensive and synoptic view of the resource from Georges Bank to Virginia. The breadth of this sampling, however, precludes the collection of fine scale information. Due to the patchy nature of scallop aggregations, inference regarding smaller resource subunits may be uncertain. Therefore, fine scale information from this survey will be used to assess the distribution and biomass of exploitable size scallops in the CAI Access Area, NLSA Access Area and the ETCA.

Methods

Survey Areas and Experimental Design

Three closed areas were surveyed during the course of this project: two areas on Georges Bank and one area in the Mid-Atlantic. The exemption areas of CAI and NLSA and the entire ETCA were sampled. The coordinates of the surveyed areas can be found in Table 1.

The sampling stations for this study were selected within the context of a systematic random grid. With the patchy distribution of sea scallops determined by some unknown combination of environmental gradients (i.e. latitude, depth, hydrographic features, etc.), a systematic selection of survey stations results in an even dispersion of samples across the entire sampling domain. The systematic grid design was successfully implemented during surveys of CAII in 1998, and CAI, NLCA and the Mid-Atlantic closed areas in 1999. This design has also been utilized for the execution of a trawl survey in the Bering Sea (Gunderson, 1993).

The methodology to generate the systematic random grid entailed the decomposition of the domain (in this case a closed area) into smaller sampling cells. The dimensions of the sampling cells were primarily determined by a maximum number of stations that could be occupied during the time allotted for the survey. Since the three closed areas were different dimensions, the distance between the stations varied. Once the cell dimensions were set, a point within the most northwestern cell was randomly selected. This point served as the starting point and all of the other stations in the grid were based on its coordinates. The station locations for the three closed areas surveyed are shown in Figures 1-2.

Sampling Gear

While at sea, the vessels simultaneously towed two dredges. A NMFS standard survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond twine top and a 1.5 inch diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 15-foot commercial scallop dredge equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. Position of twine top within the dredge bag was standardized throughout the study and rock chains were used in configurations as dictated by the area surveyed and current regulations. In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. The dredges were switched to opposite sides of the vessel mid-way throughout the trip to help minimize any bias.

For each paired tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. An inclinometer was used to determine dredge bottom contact time and high-resolution navigational logging equipment was used to accurately determine vessel position. Time stamps for both the inclinometer and the navigational log were used to determine both the location and duration fished by the dredges. Bottom contact time and vessel location were integrated to estimate area swept by the gear.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each paired tow, the entire scallop catch was placed in baskets. A fraction of these baskets were measured to estimate length frequency. The shell height of each scallop in the sampled fraction was measured in 5 mm intervals. This protocol allows for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with finfish being sorted by species and measured to the nearest 1 cm.

Samples were taken to determine area specific shell height-meat weight relationships. At 10 to15 randomly selected stations the shell height of a sample of 15 scallops was measured to the nearest 0.1 mm. The scallops were then carefully shucked and the adductor muscle individually packaged and frozen at sea. Upon return, the adductor muscle was weighed to the nearest 0.1 gram. The relationship between shell height and meat weight was estimated in log-log space using linear regression procedures in SAS v. 9.0. with the model:

$$\ln MW = \ln a + b*\ln SH$$

where MW=meat weight (grams), SH=shell height (millimeters), a=intercept and b=slope.

The standard data sheets used since the 1998 Georges Bank survey were used. The bridge log maintained by the captain/mate recorded location, time, tow-time (break-set/haul-back), tow speed, water depth, catch, bearing, weather and comments relative to the quality of the tow. The deck log maintained by the scientific personnel recorded detailed catch information on scallops, finfish, invertebrates and trash.

Data Analysis

The catch, navigation and gear mensuration data was used to estimate swept area biomass within the areas surveyed. The methodology to estimate biomass is similar to that used in analyzing the data from the 1998 survey of CAII and the 1999-2000 survey of the Mid-Atlantic closed areas. It is calculated by the following:

$$TotalBiomass = \sum_j \left(\frac{\left(\dfrac{CatchWtperTowinSubarea_j}{AreaSweptperTow} \right)}{Efficiency} \right) SubArea_j$$

Catch weight per tow

Catch weight per tow of exploitable size scallops was calculated from the raw catch data as an expanded size frequency distribution with an area appropriate shell height-meat weight relationship applied (length-weight relationships were obtained from SARC 39 document, and actual relationships taken during the cruise) (NEFSC, 2004). Exploitable biomass is defined as that fraction of the catch that is vulnerable to capture by the currently regulated commercial gear. To transform the catch from the NMFS survey dredge, two adjustments were made. The first adjustment was made to reflect documented gear performance issues as a result of the use of a liner. Based on a paired comparison between a NMFS survey dredge equipped with a liner and one without a liner, an adjustment factor of 1.428 for scallops greater than 70 mm shell height is used to adjust the catches of a lined dredge (Serchuk and Smolowitz, 1980). The second adjustment was based upon the selectivity characteristics of the commercial gear

(Yochum, 2006). This resulted in an estimate of exploitable catch weight per tow from the length frequency information gathered from the NMFS survey dredge. The catch data from the commercial dredge was not adjusted due to the fact that these data already represent that fraction of the population that is subject to exploitation by the currently regulated commercial gear.

Area Swept per tow

Utilizing the information obtained from the inclinometer and the high resolution GPS, an estimate of area swept per tow was calculated. The inclinometer which measures dredge angle was utilized to delineate the beginning and end of a survey tow. Inclinometer records were interpreted based on video ground truth efforts conducted by NMFS (Nordahl, pers. comm., 2005). An internal clock aboard the inclinometer is set to a common time based on data obtained from the GPS satellites. The internal clock on the inclinometer is updated every time data is downloaded (after the completion of every survey tow). The time stamp allows for the linkage of datasets (navigation and inclinometer) and provides an estimate of the disposition of the dredge in both time and space. Throughout the cruises the location of the ship was logged every three seconds. By determining the start and end of each tow based on inclinometer records, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

$$TowDist = \sum_{i=1}^{n} \sqrt{(long_2 - long_1)^2 + (lat_2 - lat_1)^2}$$

The linear distance of the tow is multiplied by the width of the gear to result in an estimate of the area swept by the gear during a given survey tow.

Efficiency and Domain

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of gear efficiency have been calculated from prior experiments using a variety of approaches (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). Based on those experiments and consultations with NEFSC an efficiency value of 45 % was used for the trips on Georges Bank (NLCA and CAI) and 60% was used in the mid-Atlantic (ETCA). The total area each closed area sampled was calculated in ArcView v. 3.3. This area was applied to scale the mean catch per survey tow to the appropriate area of interest.

Results

Three survey cruises were completed between June and August of 2006. Summary statistics for each cruise are shown in Table 2. Catch information is shown in Tables 3-4 and length frequency distributions for each trip are shown in Figures 3-5. Maps depicting the spatial distribution of the catches of pre-recruit (<90 mm shell height), recruit (≥90mm shell height) and total scallops from the length frequency distributions obtained by the NMFS survey dredge are shown in Figures 6-11. Based on the catch data, estimates of scallop density for each area is shown in Table 5 and estimated biomass using two different sets of shell height meat weight parameters are shown in Tables 6-7. Shell height meat weight relationships were generated for all areas. The resulting parameters are shown in Table 8. Graphical comparisons between the fitted curves from the data from the survey cruises and the parameters for the mid-Atlantic and Georges Bank contained in SARC 39 are shown in Figures 12-13 (NEFSC, 2004). Catch per unit effort of finfish and invertebrate bycatch for the three cruises is shown in Tables 9-11.

Discussion

Fine scale surveys of closed areas area an important endeavor. These surveys provide information about subsets of the resource that may not have been subject to intensive sampling by other efforts. Additionally, the timing of industry based surveys can be tailored to give managers current information to guide important management decisions. This information can help time access to closed areas and help set Total

Allowable Catches (TAC) for the re-opening. Finally, this type of survey is important in that it involves the stakeholders of the fishery in the management of the resource.

The use of commercial scallop vessels in a project of this magnitude presents some interesting challenges. One such challenge is the use of the commercial gear. This gear is not designed to be a survey gear; it is designed to be efficient in a commercial setting. The design of this current experiment however provides insight into the utility of using a commercial gear as a survey tool. The concurrent use of two different dredge configurations provides an excellent test for agreement of results. With a paired design, it is assumed that the two gears cover the same bottom and sample from the same population of scallops. The expectation that after applying the appropriate adjustment factors to compensate for gear performance issues the estimates of biomass for the two gears will be comparable. Based on the biomass estimates for the three areas, there is a clear trend that indicates biomass values from point estimates obtained from the commercial gear are higher relative to those from the NMFS survey gear. The possibility exists that there is a differential efficiency between the two gears. At this point, it was assumed that the overall efficiency of the two gears was the same. Information from the selectivity analysis seems to indicate that, at least on a relative basis (based on the estimates of the split parameter, p) the commercial gear is more efficient (Yochum, 2006). While much work has been done to estimate the efficiency of the commercial dredge, there has been little effort devoted to examining the overall efficiency of the NMFS survey dredge (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). To increase the utility of the NMFS survey dredge from a tool that produces a relative index to one that is fine tuned to produce absolute biomass estimates, the efficiency question should be viewed as a high priority.

Based on the results of this study, the commercial gear has the potential to be an effective sampling gear under some circumstances. Due to the selective properties of a dredge equipped with 4.0 inch rings, it will never be an effective tool for sampling small scallops. Its strength lies in sampling exploitable size scallops (> 80 mm shell height). Although the selectivity work done by Yochum, (2006) provides an experimental basis to calculate the probability that smaller scallops will be retained by the commercial gear, detection of recruitment events in their early stages will never be a strength of the commercial gear.

Biomass estimates are sensitive to other assumptions made about the biological characteristics of the resource. Specifically, the use of an appropriate shell height meat weight parameters. Parameters generated from data collected during the course of the study were appropriate for the area and time sampled. There is however, a large variation in this relationship as a result of many factors. Seasonal variation can result in some of the largest differences in shell height meat weight values. Traditionally, when the sea scallop undergoes its annual spawning cycle the somatic tissue of the scallop is still recovering and is at some of their lowest levels relative to shell size (Serchuk and Smolowitz, 1989). So while accurately representative for the month of the survey, biomass has the potential to be different relative to relative to other times of the year. For comparative purposes, our results were also shown using the parameters from SARC 39 (NEFSC, 2004). This allowed a comparison of biomass estimates with other data sources. Area and time specific shell height: meat weight parameters are another topic that merits consideration.

The survey of the three closed areas during the spring/summer of 2006 provided a high resolution view of the resource in those discrete areas. These closed areas are unique in that they play varied roles in the spatial management of the sea scallop resource. While the data and subsequent analyses provide an additional source of information on which to base management decisions, it also highlights the need for further refinement of some of the components of industry based surveys. The use of industry based cooperative surveys provides an excellent mechanism to obtain the vital information to effectively regulate the sea scallop fishery in the context of an area management strategy.

Table 1 Boundary coordinates of the closed areas sampled during the 2006 surveys.

Elephant Trunk	**Latitude**	**Longitude**
ET-1	38° 50’	74° 20’
ET-2	38° 10’	74° 20’
ET-3	38° 10’	73° 30’
ET-4	38° 50’	73° 30’
Closed Area I		
CAI-1	41° 26’ N	68° 30’ W
CAI-2	41° 09’ N	68° 30’ W
CAI-3	41° 4.54’ N	69° 0.9’ W
Nantucket Lightship		
NLCA-1	40° 50’ N	69° 00’ W
NLCA-2	40° 30’ N	69° 00’ W
NLCA-3	40° 30’ N	69° 4.5’ W
NLCA-4	40° 50’ N	69° 29.5’ W

Table 2 Summary statistics for the three survey cruises. Station were excluded from the estimation of biomass due to “bad” tows and as a result of ancillary comparative tows completed during the same cruise.

Area	**Cruise dates**	**Number of tows conducted**	**Number of stations included in biomass estimate**
Elephant Trunk	June 5-12, 2006	112	82
Closed Area I	Aug. 15-21, 2006	45	34
Nantucket Lightship	Aug. 15-21, 2006	51	39

Table 3 Mean catch of exploitable sea scallops during the 2006 cooperative surveys of the exemption areas of Georges Bank Closed Area I, Nantucket Lightship Closed Area and the Elephant Trunk Closed Area. Mean catch is depicted as a function of the shell height meat weight relationship as observed on the cruise. For the Elephant Trunk Closed Area the shell height meat weight relationship collected on the October 2005 VIMS cooperative survey was used for comparative purposes to illustrate the breadth of seasonal variation in meat yields.

Area	Gear	Area (km^2)	Samples	Mean (g/tow)	Std. Dev.	CV %
Elephant Trunk						
	Commercial	4,546.00	82	54,478.03	60,096	12.18
	Survey	4,546.00	82	24,073.01	21,906	10.04
Closed Area I						
	Commercial	674.42	34	44,369.05	67,228	25.98
	Survey	674.42	34	17,111.84	17,981	18.02
Nantucket Lightship						
	Commercial	1,145.54	39	69,532.63	74,151	17.07
	Survey	1,146.54	39	28,865.78	30,586	16.96

Table 4 Mean catch of exploitable sea scallops during the 2006 cooperative surveys of the exemption area of Georges Bank Closed Area I, Nantucket Lightship Closed Area and the Elephant Trunk Closed Area. Mean catch is depicted as a function of the shell height meat weight relationship for the respective resource area as found in SARC 39 (NEFSC, 2004).

Area	Gear	Area (km^2)	Samples	Mean (g/tow)	Std. Dev.	CV %
Elephant Trunk						
	Commercial	4,546.00	82	66,377.71	74,060	12.32
	Survey	4,546.00	82	29,322.62	26,710	10.05
Closed Area I						
	Commercial	674.42	34	42,958.49	65,029	25.96
	Survey	674.42	34	16,567.71	17,405	18.01
Nantucket Lightship						
	Commercial	1,145.54	39	60,120.15	64,081	17.06
	Survey	1,146.54	39	24,973.15	26,466	16.97

Table 5 Estimated density of exploitable scallops by gear (commercial, survey) for the three closed areas surveyed during the spring/summer 2006. Gear efficiency values of 45% were used for the two Georges Bank areas and 60% for the Elephant Trunk.

Area	Gear	Area (km^2)	Samples	Density (scal/m^2)	Std. Dev.	CV %
Elephant Trunk						
	Commercial	4,546.00	82	0.56	0.755	14.87
	Survey	4,546.00	82	0.46	0.459	10.94
Closed Area I						
	Commercial	674.42	34	0.278	0.481	29.71
	Survey	674.42	34	0.201	0.224	19.04
Nantucket Lightship						
	Commercial	1,145.54	39	0.376	0.400	17.02
	Survey	1,146.54	39	0.299	0.322	17.17

Table 6 Estimated biomass of exploitable scallops by gear (commercial, survey) for the three closed areas surveyed during the spring/summer of 2006. Exploitable biomass is defined as those scallops vulnerable to the commercial scallop dredge as defined in Yochum (2006). Shell height meat weight parameters from samples taken during each cruise. For the Elephant Trunk Closed Area the shell height meat weight relationship collected on the October 2005 VIMS cooperative survey was used for comparative purposes to illustrate the breadth of seasonal variation in meat yields. Gear efficiency values of 45% were used for the two Georges Bank area and 60% for the Elephant Trunk. 95% confidence intervals (CI) were calculated as ± 1.96*(variance of biomass)$^{1/2}$ (Gunderson, 1993).

Area	Gear	Biomass (mt)	Lower bound 95% CI	Upper Bound 95% CI
Elephant Trunk	Commercial	51,079.00	41,632.04	60,525.96
	Survey	42,320.69	35,863.81	48,777.56
Closed Area I	Commercial	7,581.60	4,991.27	10,171.94
	Survey	5,491.46	4,190.31	6,781.54
Nantucket Lightship	Commercial	20,477.34	15,879.69	25,075.00
	Survey	15,939.31	12,383.45	19,495.16

Table 7 Estimated biomass of exploitable scallops by gear (commercial, survey) for the three closed areas surveyed during the spring/summer of 2006. Exploitable biomass is defined as those scallops vulnerable to the commercial scallop dredge as defined in Yochum (2006). Gear efficiency values of 45% were used for the two Georges Bank area and 60% for the Elephant Trunk. Shell height meat weight parameters from SARC 39 document (NEFSC, 2004). 95% confidence intervals (CI) were calculated as ± 1.96*(variance of biomass)$^{1/2}$ (Gunderson, 1993).

Area	Gear	Biomass (mt)	Lower bound 95% CI	Upper Bound 95% CI
Elephant Trunk				
	Commercial	62,236.23	50,594.13	73,878.32
	Survey	51,549.57	43,676.66	59,422.48
Closed Area I				
	Commercial	7,340.57	4,834.94	9,846.20
	Survey	5,308.17	4,050.72	6,565.61
Nantucket Lightship				
	Commercial	17,705.37	13,732.11	21,678.62
	Survey	13,789.85	10,712.93	16,866.77

Table 8 Summary of shell height-meat weight parameters for the three closed areas sampled during the course of the survey and the parameters from SARC 39 (NEFSC, 2004).

Area surveyed	Month	N	a	b
Survey data				
Nantucket Lightship	August, 2006	163	-11.821	3.1855
Closed Area I	August, 2006	188	-11.453	3.088
Elephant Trunk	June, 2006	174	-13.027	3.4105
Elephant Trunk	October, 2005	210	-13.8128	3.5512
SARC 39				
Georges Bank	-	-	-11.6038	3.1221
Mid-Atlantic	-	-	-12.2484	3.2641

Table 9 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the VIMS-Industry cooperative study of the Elephant Trunk Closed Area during June of 2006. In total, finfish and invertebrate bycatch was measured and recorded for 82 survey tows.

Common Name	Scientific Name	Commercial Dredge	Survey Dredge
Unclassified Skates	Raja spp.	12.61	7.70
Silver Hake	Merluccius bilinearis	0.00	0.53
Red Hake	Urophycis shuss	0.00	0.11
Summer Flounder	Paralichtys dentatus	0.00	0.01
Fourspot Flounder	Paralichtys oblongotus	0.24	1.50
Yellowtail Flounder	Limanda ferruginea	0.01	0.18
Witch Flounder	Glyptocephalus cynoglossus	0.01	0.05
Windowpane Flounder	Scophthalmus aquasus	0.02	0.07
Gulfstream Flounder	Citharichthys arctifrons	0.01	0.68
Sculpin uncl.	Cottidae	0.00	0.04
Armored Searobin	Peristedion miniatum	0.13	0.61
Monkfish	Lophius americanus	0.62	0.70
American lobster	Homarus americanus	0.02	0.02
Squid Uncl.	Cephalopoda	0.00	0.04

Table 10 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the VIMS-Industry cooperative study of Closed Area I during August of 2006. In total, finfish and invertebrate bycatch was measured and recorded for 34 survey tows.

Species	Scientific Name	Commercial Dredge	Survey Dredge
Spiny dogfish	Squalus acanthias	0.12	0.03
Unclassified Skates	Raja spp.	38.53	14.15
Barndoor Skate	Raja laevis	2.71	0.68
Silver Hake	Merluccius bilinearis	0.03	1.00
Haddock	Melanogrammus aeglefinus	0.00	0.09
Red Hake	Urophycis shuss	0.47	33.88
Summer Flounder	Paralichtys dentatus	0.06	0.03
Fourspot Flounder	Paralichtys oblongotus	0.68	1.26
Yellowtail Flounder	Limanda ferruginea	0.21	1.12
Blackback Flounder	Psuedopleuronectes americana	1.47	0.62
Witch Flounder	Glyptocephalus cynoglossus	0.24	0.41
Windowpane Flounder	Scophthalmus aquasus	0.76	1.24
Gulfstream Flounder	Citharichthys arctifrons	0.00	0.09
Sculpin uncl.	Cottidae	0.24	1.53
Sea Raven	Hemitripterus americanus	0.18	0.21
Armored Searobin	Peristedion miniatum	0.00	0.03
Monkfish	Lophius americanus	7.15	4.32
American lobster	Homarus americanus	0.18	0.03
Squid Uncl.	Cephalopoda	0.03	0.00

Table 11 Catch per unit effort (a unit of effort is represented by one standard survey tow of 15 minute duration at 3.8 kts.) of finfish and invertebrate bycatch encountered during the VIMS-Industry cooperative study of the Nantucket Lightship Closed Area during August of 2006. In total, finfish and invertebrate bycatch was measured and recorded for 38 survey tows.

Species	Scientific Name	Commercial Dredge	Survey Dredge
Unclassified Skates	Raja spp.	41.03	18.47
Barndoor Skate	Raja laevis	0.47	0.24
Silver Hake	Merluccius bilinearis	0.16	3.13
Haddock	Melanogrammus aeglefinus	0.03	0.08
Red Hake	Urophycis shuss	0.53	20.18
Summer Flounder	Paralichtys dentatus	0.18	0.32
Fourspot Flounder	Paralichtys oblongotus	1.32	3.53
Yellowtail Flounder	Limanda ferruginea	2.61	17.11
Blackback Flounder	Psuedopleuronectes americana	0.24	0.45
Witch Flounder	Glyptocephalus cynoglossus	0.03	0.00
Windowpane Flounder	Scophthalmus aquasus	3.58	6.18
Gulfstream Flounder	Citharichthys arctifrons	0.03	5.79
Sculpin uncl.	Cottidae	1.76	5.16
Sea Raven	Hemitripterus americanus	0.03	0.13
Armored Searobin	Peristedion miniatum	0.13	0.13
Monkfish	Lophius americanus	2.74	1.69
American lobster	Homarus americanus	0.00	0.03

Figure 1 Locations of sampling stations in the Elephant Trunk Closed Area survey by the F/V *Carolina Boy* during the cruise conducted June 2006.

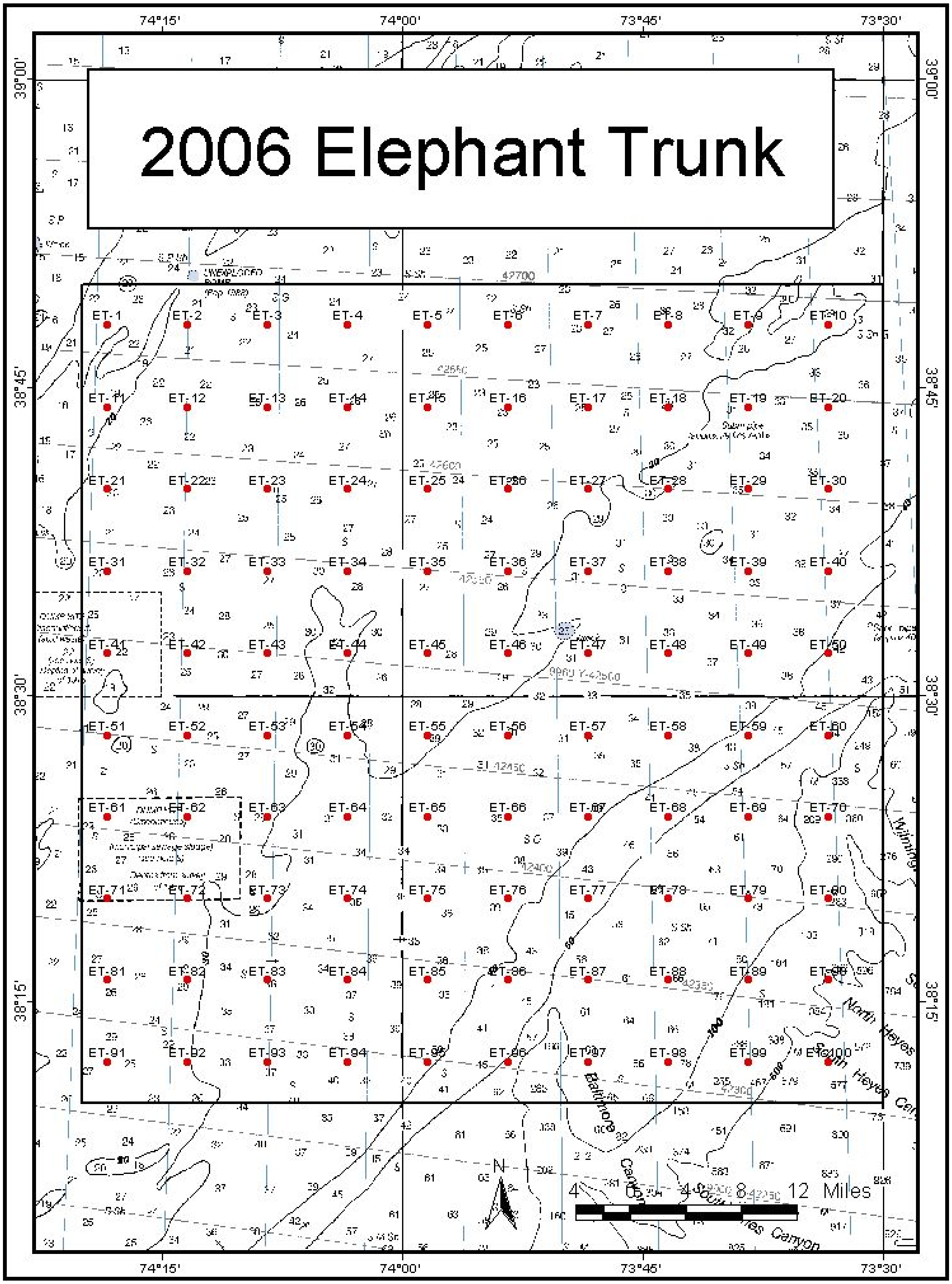


Figure 2 Locations of sampling stations in Nantucket Lightship and Closed Area I survey by the F/V *Celtic* during the cruise conducted during August 2006.

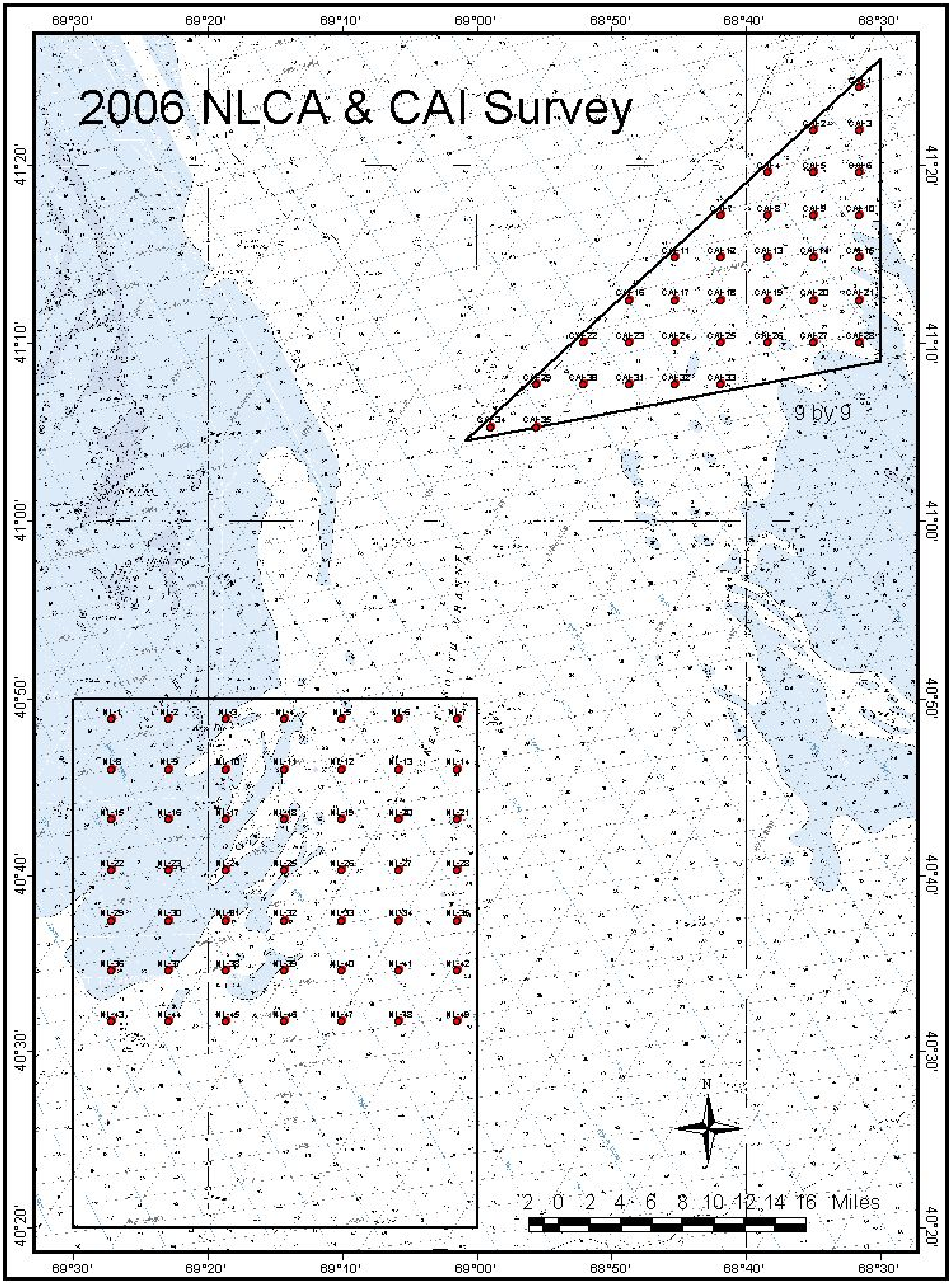


Figure 3 Shell height frequencies for the cooperative survey of the Elephant Trunk Closed Area aboard the F/V *Carolina Boy* conducted June, 2006. The two frequencies represent the unadjusted catches from the two gears used during the survey.

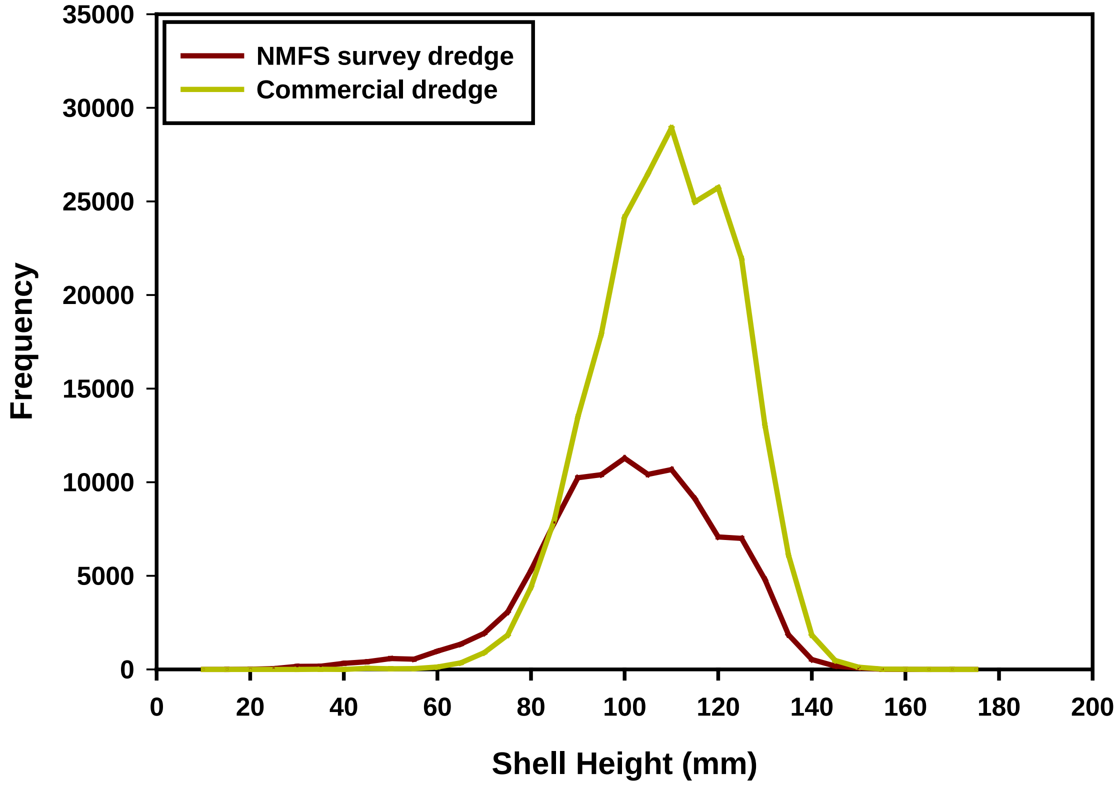
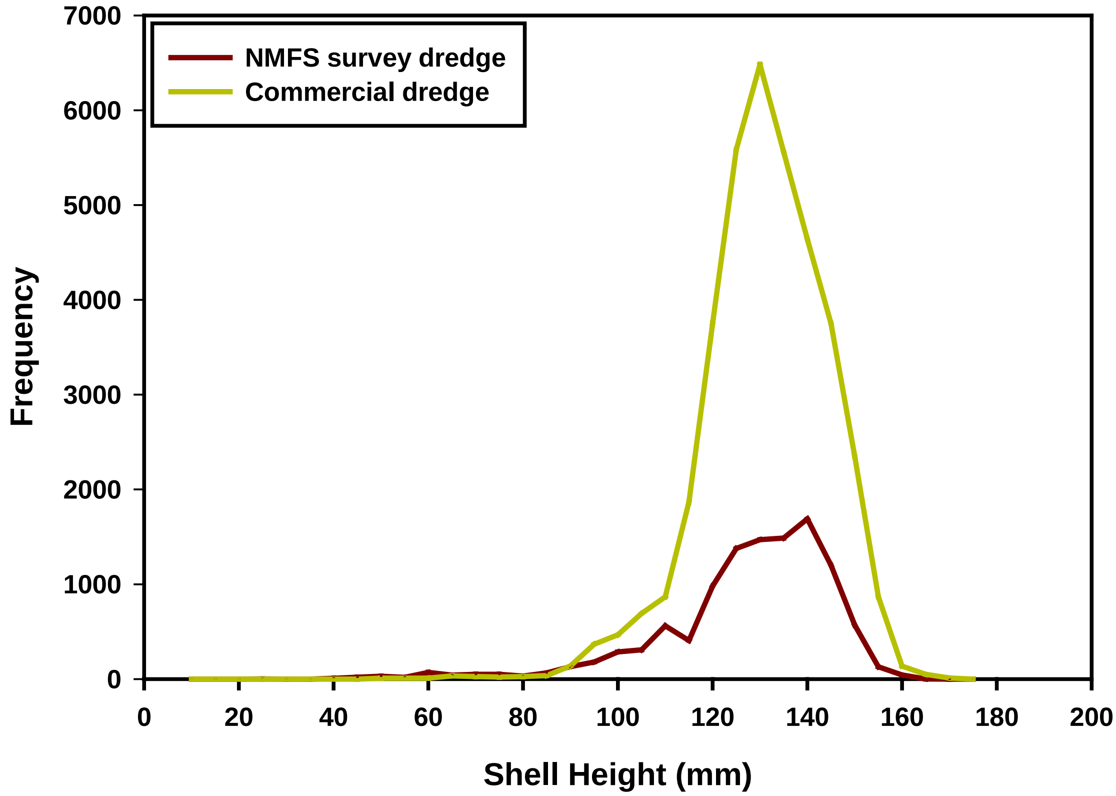


Figure 4 Shell height frequencies for the cooperative survey of Closed Area I aboard the F/V *Celtic* conducted August, 2006. The two frequencies represent the unadjusted catches from the two gears used during the survey.



<u>Figure 5</u> Shell height frequencies for the cooperative survey of Nantucket Lightship Closed Area aboard the F/V *Celtic* conducted August, 2006. The two frequencies represent the unadjusted catches from the two gears used during the survey.

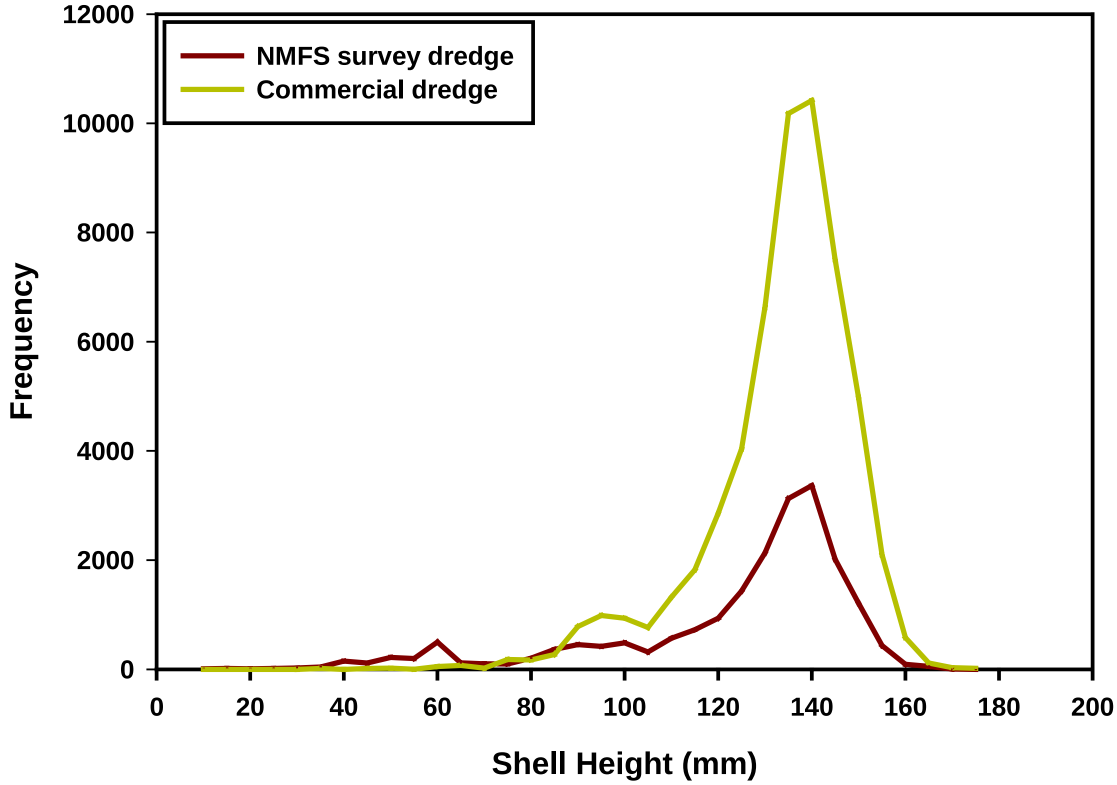


Figure 6 Distribution of pre-recruit scallops (<90 mm) in the Elephant Trunk Closed Area derived from the catches by the NMFS survey dredge aboard the F/V *Carolina Boy* during June of 2006.

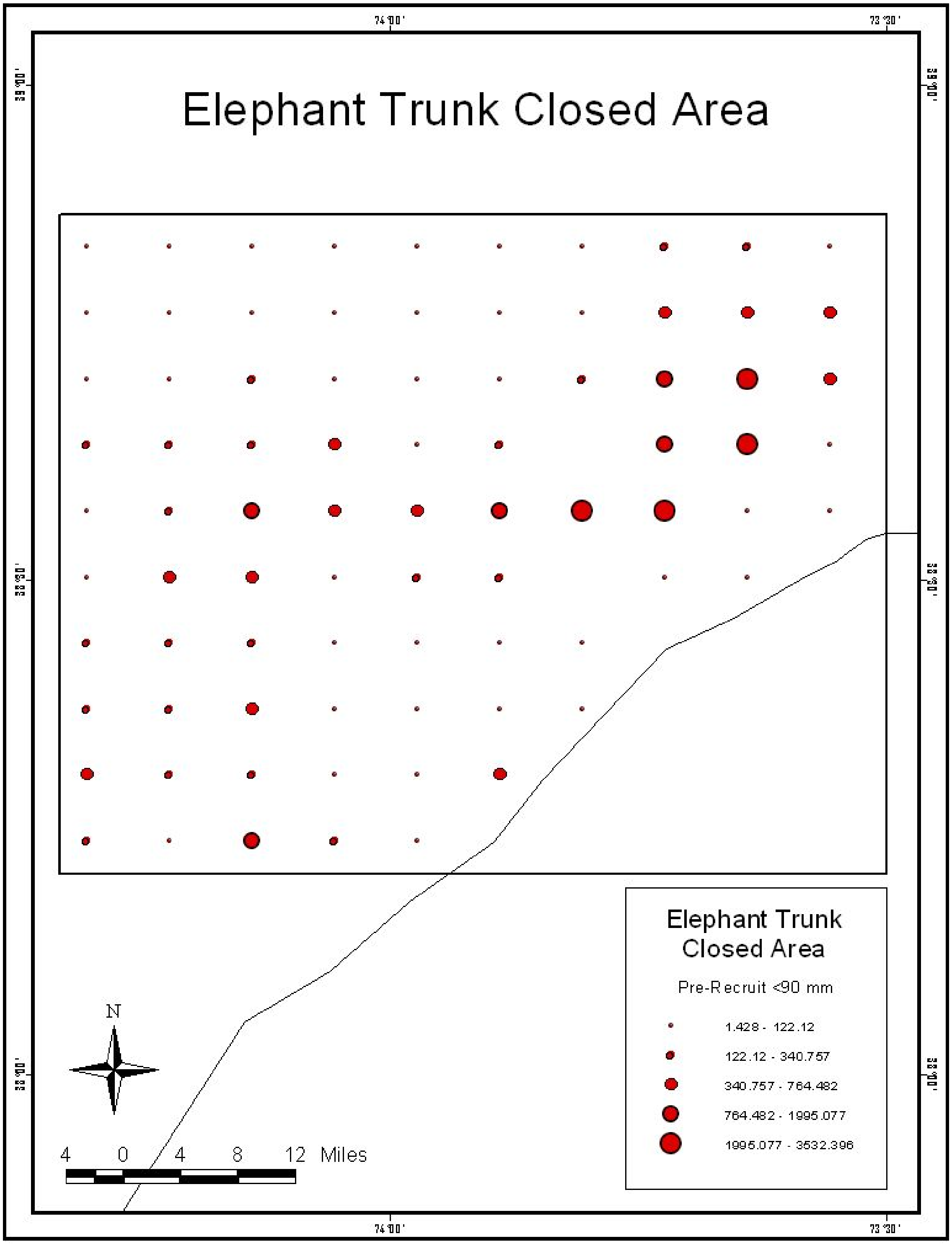


Figure 7 Distribution of recruit scallops (≥90 mm) in the Elephant Trunk Closed Area derived from the catches by the NMFS survey dredge aboard the F/V *Carolina Boy* during June of 2006.

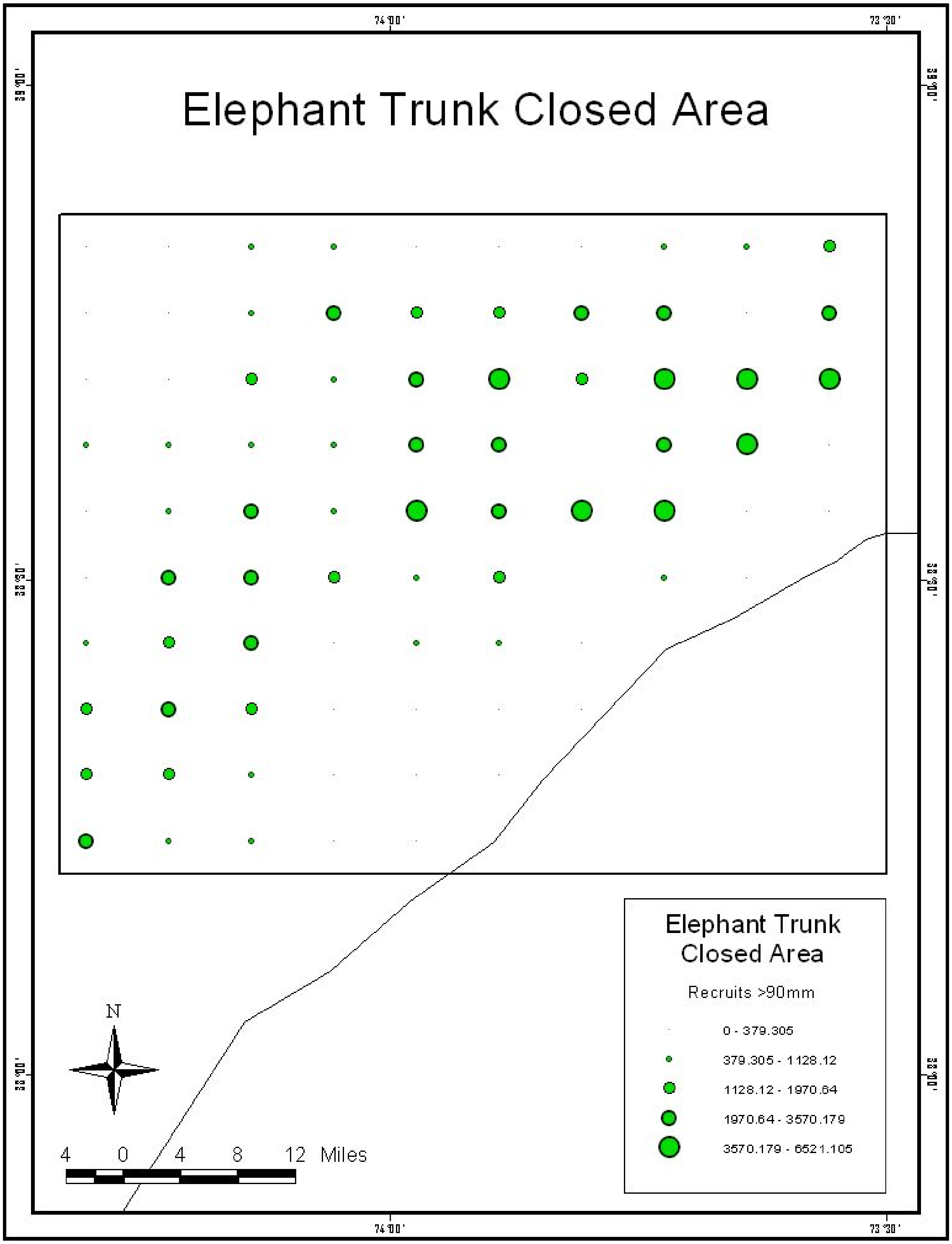


Figure 8 Distribution of total scallops in the Elephant Trunk Closed Area derived from the catches by the NMFS survey dredge aboard the F/V *Carolina Boy* during June of 2006.

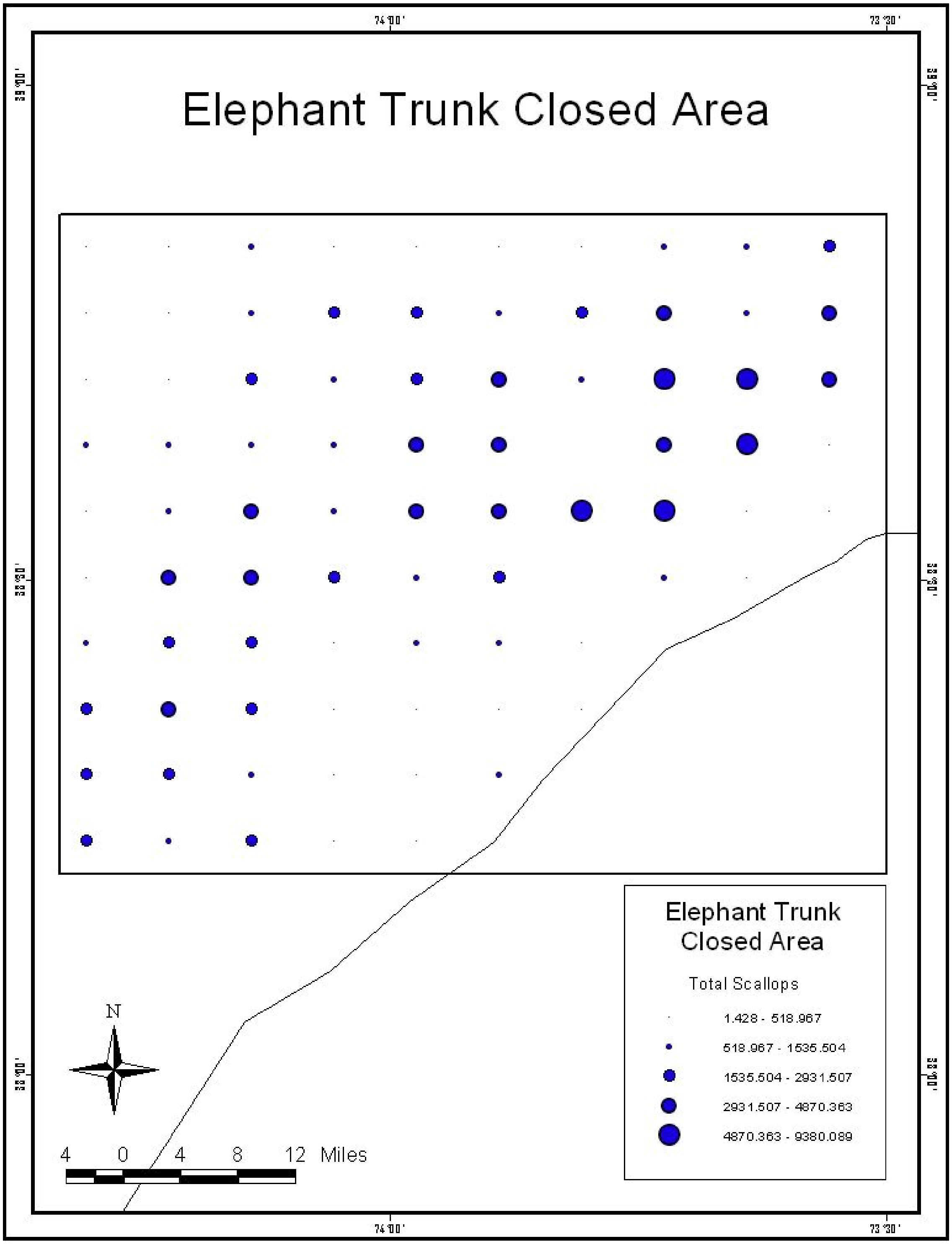


Figure 9 Distribution of pre-recruit scallops (<90 mm) in Nantucket Lightship and Closed Area I Area derived from the catches by the NMFS survey dredge aboard the F/V *Celtic* during August of 2006.

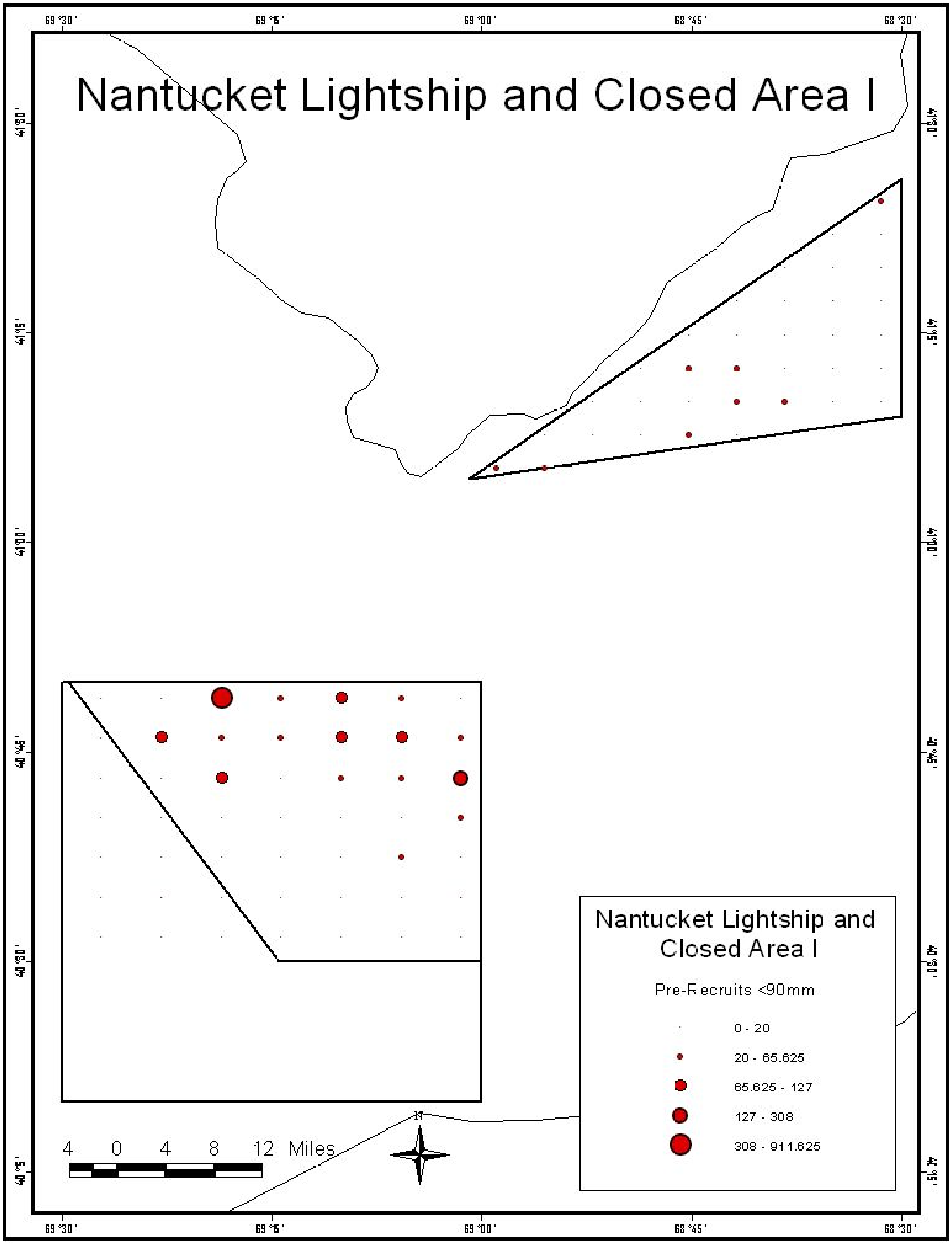


Figure 10 Distribution of recruit scallops (≥90 mm) in Nantucket Lightship and Closed Area I Area derived from the catches by the NMFS survey dredge aboard the F/V *Celtic* during August of 2006.

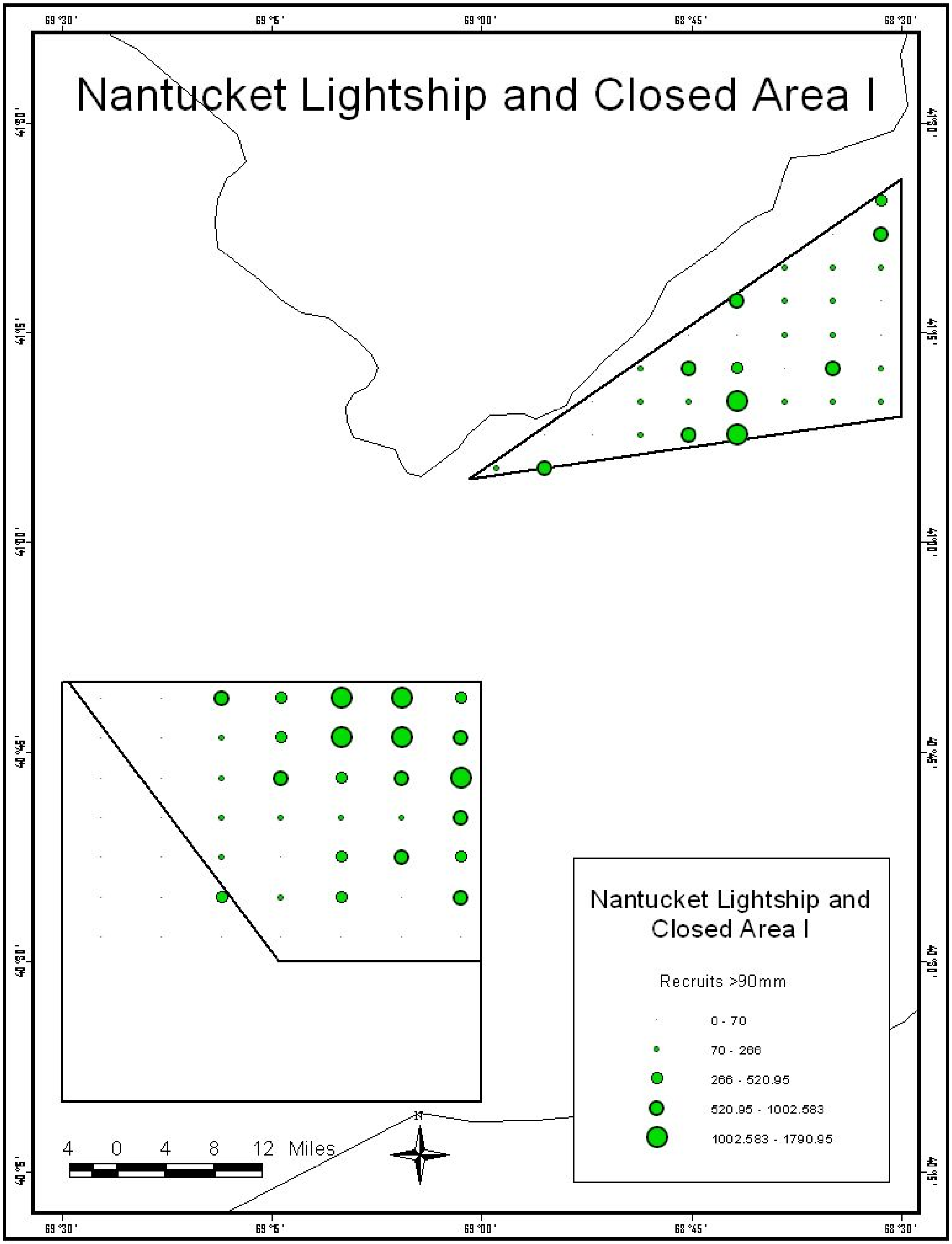
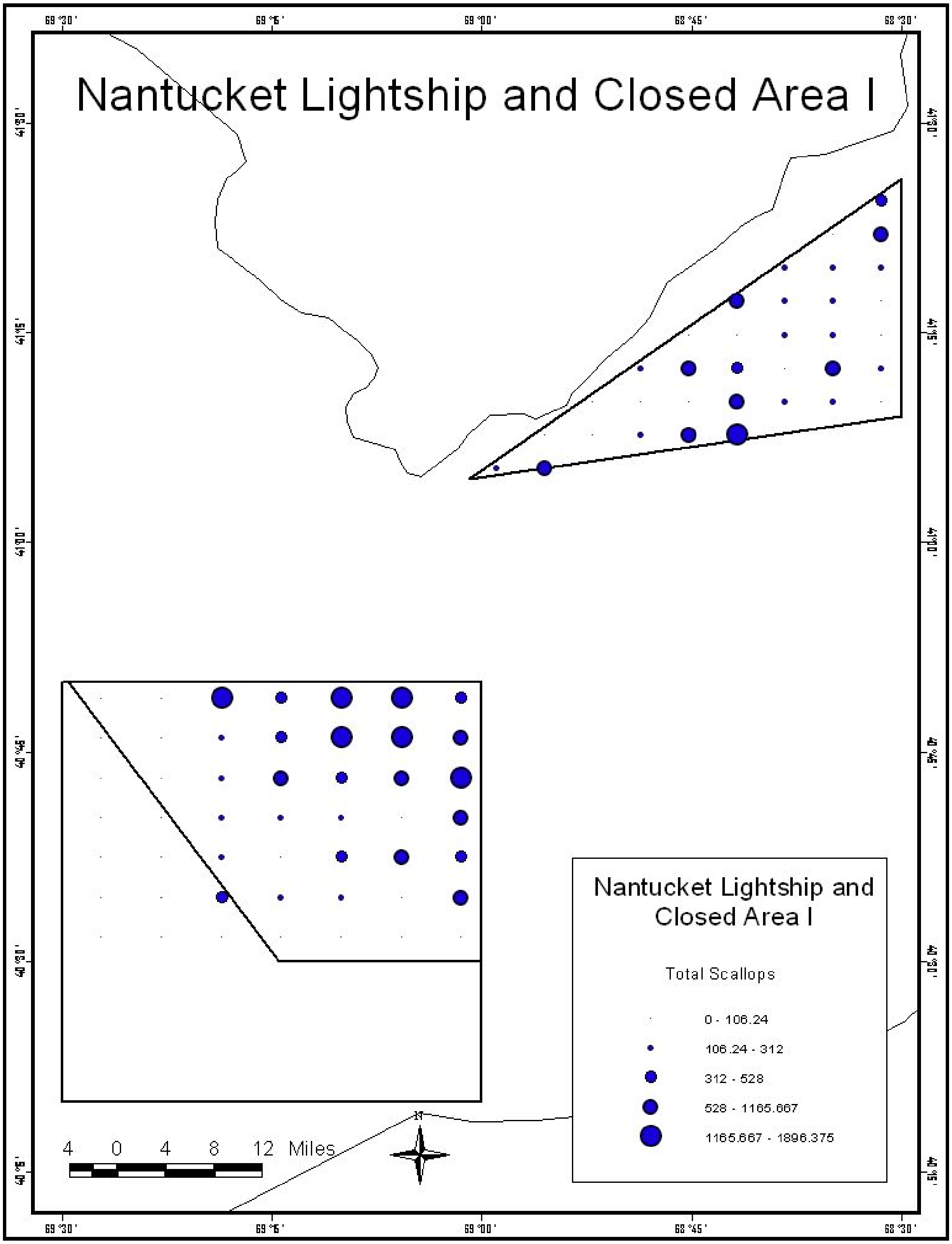
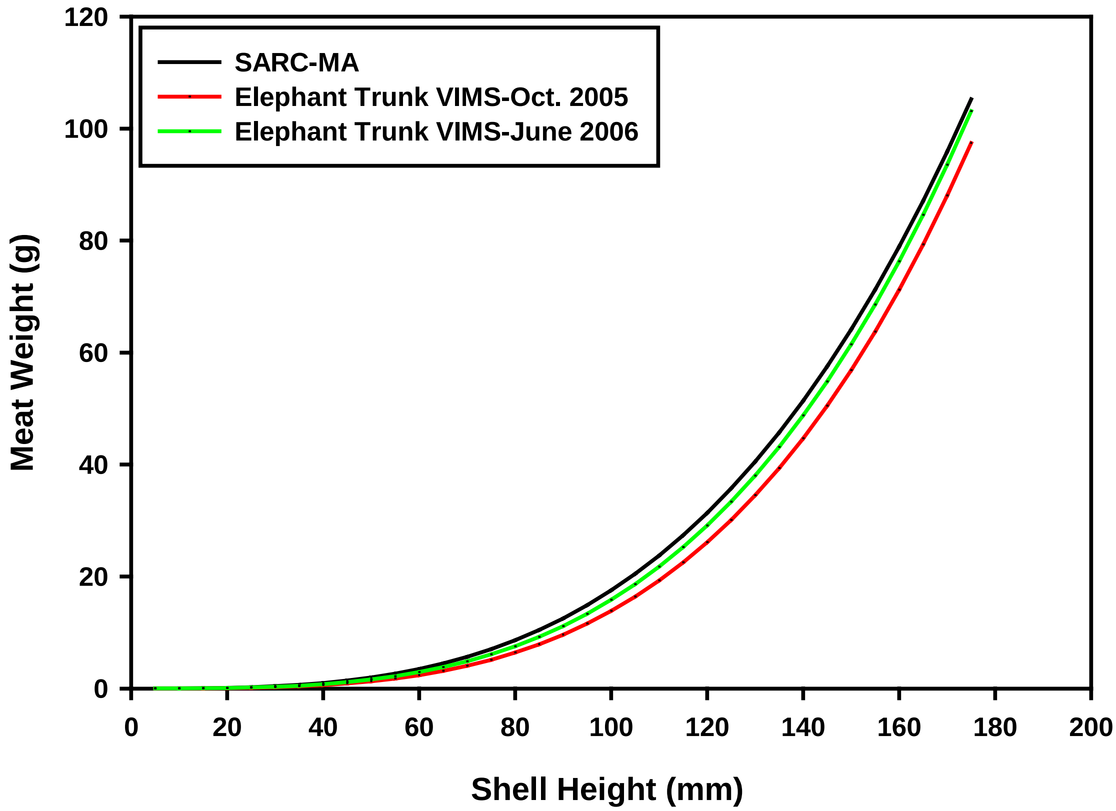


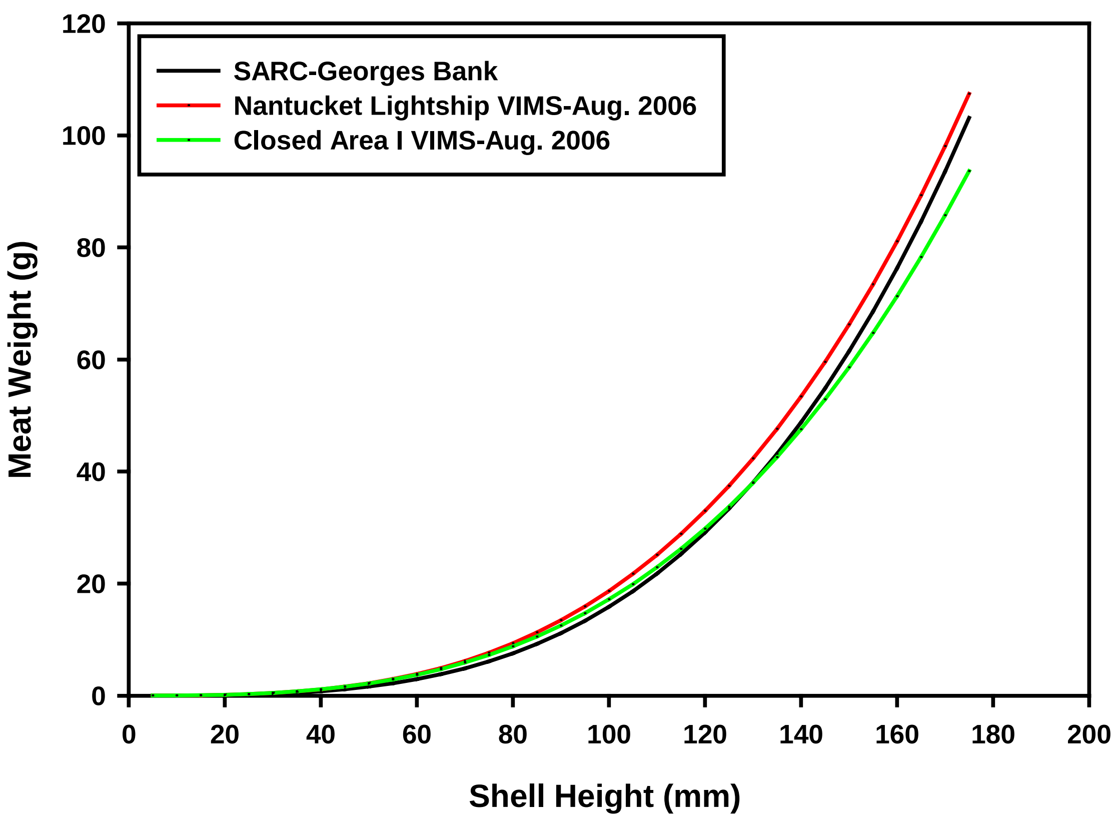
Figure 11 Distribution of total scallops in Nantucket Lightship and Closed Area I Area derived from the catches by the NMFS survey dredge aboard the F/V *Celtic* during August of 2006.



<u>Figure 12</u> Comparison between fitted shell height-meat weight relationships. The two curves are the product of parameters generated from different sources. The curves labeled Elephant Trunk VIMS-Oct. 2005 and Elephant Trunk VIMS-June 2006 were generated from data collected during the survey cruises conducted aboard the F/V *Carolina Boy* during October 2005 and June 2006. The curve labeled SARC-MA was generated from parameters contained SARC 39 (NEFSC, 2004).



<u>Figure 13</u> Comparison between fitted shell height-meat weight relationships. The three curves are the product of parameters generated from different sources. The curves labeled Nantucket Lightship VIMS Aug. 2006 and Closed Area I VIMS-Aug. 2006 were generated from data collected during survey cruises conducted aboard the F/V *Celtic* during August 2006. The curve labeled SARC-GB was generated from parameters for the entire Georges Bank region contained SARC 39 (NEFSC, 2004).



Literature Cited

DuPaul, W.D., E.J. Heist, and J.E. Kirkley, 1989. Comparative analysis of sea scallop escapement/retention and resulting economic impacts. College of William & Mary, Virginia Institute of Marine Science, Gloucester Point, VA. VIMS Marine Resource Report 88-10. 70 pp.

DuPaul, W.D. and J.E. Kirkley, 1995. Evaluation of sea scallop dredge ring size. Contract report submitted to NOAA, National Marine Fisheries Service. Grant # NA36FD0131.

Gedamke, T., W.D. DuPaul, and J.M. Hoenig. 2004. A Spatially Explicit Open-Ocean DeLury Analysis to Estimate Gear Efficiency in the Dredge Fishery for Sea Scallop *Placopecten magellanicus*. North American Journal of Fisheries Management 24:335-351.

Gedamke, T., W.D. DuPaul, and J.M. Hoenig. 2005. Index-Removal Estimates of Dredge Efficiency for Sea Scallops on Georges Bank. North American Journal of Fisheries Management 25:1122-1129.

Gunderson, D.R. 1993. Surveys of Fisheries Resources. John Wiley & Sons, Inc. New York, NewYork.

Northeast Fisheries Science Center. 2004. 39th Northeast Regional Stock Assessment Workshop (39th SAW) assessment summary report. *U.S. Dep. Commer., Northeast Fish. Sci. Cent. Ref. Doc.* 04-10a; 16 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

Serchuk, F.M. and Smolowitz, R.J. 1980. Size Selection of Sea Scallops by an Offshore Scallop Survey Dredge. ICES C.M. K:24. 38 pp.

Serchuk, F.M. and Smolowitz, R.J. 1989. Seasonality in sea scallop somatic growth and reproductive cycles. J. Shellfish Res.. 8:435.

Stokesbury, K.D. 2002. Estimation of sea scallop abundance in closed areas of Georges Bank, USA. Trans. of the Amer. Fish. Soc. 131:1081-1092.

Van Voorhees, D. 2006. Fisheries of the United States, 2005. NMFS Office of Science and Technology, Fisheries Statistics Division.

Yochum, N. 2006. Size-Selectivity of the Commercial Sea Scallop (*Placopecten magellanicus)* Dredge. College of William and Mary, Virginia Institute of Marine Science. Masters Thesis